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Corporate carbon footprint for country Climate Change mitigation: A case study of a tannery in Turkey

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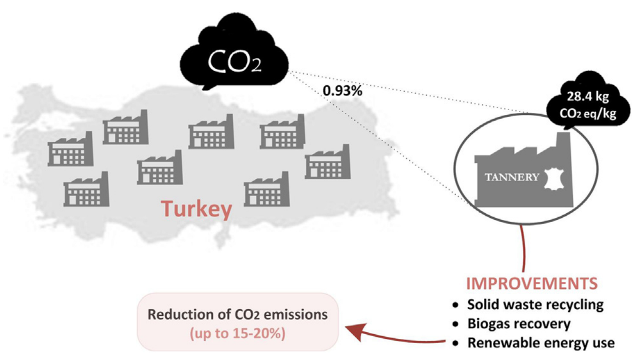
HIGHLIGHTS

- Inventory data for Turkish tannery published for the first time.
- Carbon footprint of tanneries and options for improvement presented
- Contribution of corporate carbon footprint (CCF) to Turkey's GHG mitigation strategy
- Turkish emission factors need to be published for wider CCF calculations.
- Findings important for Turkish companies to compete in international green markets

GRAPHICAL ABSTRACT



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ABSTRACT

Assessment of carbon emissions and environmental impact of production is indispensable to achieve a sustainable industrial production in Turkey, especially for those companies willing to compete in new international green markets. In this case study, corporate carbon footprint of a representative Turkish tanning company was analyzed. Inventory and impact data are presented to help in the environmental decision-making process. The results indicate that significant environmental impacts were caused during the landfilling of solid wastes as well as the production of the electricity and fuel required in the tannery. Turkish tannery inventory data presented here for the first time will be useful for leather tanning company managers to calculate sustainability key indicators.

Improving alternatives at country level were identified (increasing the renewable sources on electricity production and promote energy recovery in landfills) which would be useful not only to decrease greenhouse gas (GHG) emissions of tanning sector but also of other industries requiring electricity and producing organic wastes. Considering the substantial contribution of industrial processes to the Turkish carbon emissions (15.7%) (TUIK, 2013), work done on those areas would provide a sound improvement in environmental profile of Turkey. The importance to promote a national strategy to reduce GHG emissions in Turkey was discussed here, as well as its relation to corporate carbon footprint assessments.

One of the significant points revealed from the case study is the lack of published country specific emission factors for Turkey, which is a fundamental prerequisite to promote corporate carbon footprint assessment within the country.

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1. Introduction

1.1. Leather industry and climate change in Turkey

Turkey is considered as a newly industrialized country with a background of rapid economic growth. Industry is one of the three major contributors to CO_2 emissions Turkish economy (OECD/IEA, 2016). Although Turkey's greenhouse gas emissions (GHGs) as carbon dioxide equivalent (CO_2-eq) (6.02 t CO_2/capita) is below OECD[1] Europe average of 8.31 t CO_2/capita (Akbostancı et al., 2011; OECD/IEA, 2016) the shares of CO_2 emissions have increased by 118% in 2014 compared to the emissions in 1990 and reflects its rapid industrial growth and increase in energy consumption associated with increasing demand (TUIK, 2016). Furthermore in line with Turkey's development targets the level of CO_2 emission is foreseen to rise six-fold by 2025 with respect to the level of emissions in 1990 (Lise, 2006).

Leather and leather product industry is one of the foremost traditional sectors of Turkey, with an annual export value around US$ 1.3 million in 2015, and footwear is the most important item (51% of total leather goods exports) (Leather Wear Report, 2016). Over the past decade the evolution of climate change into a global concern and increasing awareness on the environmental impact of production processes has enforced leather manufacturers to provide more information and to meet higher environmental standards.

1.2. Leather processes and life cycle assessment

Life cycle assessment (LCA) is a widely accepted methodology that has proven its efficiency as a good decision-making tool for the assessment of the environmental burdens associated with production processes to move towards sustainable production practices. There are a number of applications of LCA methodology in the field of leather production at different geographical locations such as Spain, India, Chile etc.(Joseph and Nithya, 2009; Puig et al., 2007; Rivela et al., 2004) with various system boundaries comprising all system or only one process step (Castiello et al., 2008; Kiliç et al., 2011) and different flow references referring to the delivery of a leather surface area or to the tanning of a certain weight of raw hide (Milà et al., 1998; Notarnicola et al., 2011).

First applications of LCA on leather industry took place in the nineties at European tanneries. Milà et al. (1998) conducted a life cycle study in the Spanish leather industry on a cradle-to-grave basis in order to identify the environmental 'hot spots' in the footwear life cycle. These authors further applied LCA in order to detect the environmental 'hot spots' of chrome-tanned bovine leather industry and provide environmental information to The Autonomous Government of Catalonia for the establishment of environmental criteria in the Catalan eco-label. In both studies detailed inventory data was not provided. Only environmental results for chrome-tanned leather were presented for different impact categories (Milà et al., 2002).

Rivela et al. (2004) carried out a LCA by studying a representative leather tannery industry in Chile. Authors included both technical and economic analysis to quantify and evaluate the impacts of the chromium tanning process and further improvement actions were proposed. Joseph and Nithya (2009) made an attempt to investigate the material flows of Indian leather by applying a life cycle analysis approach in order to get an idea about the environmental burdens of leather products.

A number of life cycle assessment case studies were conducted to evaluate the environmental performance of alternative technologies in order to investigate the feasibility of applying cleaner production principles as a tool for improving the environmental and economical quality in the leather tanning industry. Within this context the soaking, unhairing and liming processes were evaluated under the LCA perspective and comparative environmental performances of the alternative methods were presented by various researchers (Castiello et al., 2008; Nazer et al., 2006). Nazer et al. (2006) applied LCA as a decision support tool to evaluate the net environmental benefits of using unhairing-liming liquids several times after being recharged with reduced quantities of chemicals and results were expressed in eco-points. Castiello et al. (2008) made another attempt to evaluate the actual reduction of the environmental impact of conventional unhairing process, by applying an alternative oxidative unhairing process that eliminates the use of sulphides. Another comparative LCA was carried out to analyze the environmental performance of chemical and enzyme-assisted soaking and unhairing/liming processes in a Chinese tannery. Environmental impacts of producing and delivering the enzymes to the tannery, chemicals and electricity savings have been evaluated in terms of energy consumption and contribution to global warming (Nielsen, 2006; Notarnicola et al., 2011) put some effort to analyze Spanish and Italian product-systems regarding bovine leather manufacturing, and carried out LCA to find out if the different technologies and management solutions adopted led to significant environmental differences in the two system analyzed. It is one of the detailed comparative LCA studies in European tannery systems with available inventory data regarding each phase of tanning process.

Waste minimization in tannery sludge management was another issue that has been evaluated under LCA perspective for environmental comparison of alternative processes. Kiliç et al. (2011) made some efforts to evaluate three tannery waste treatment scenarios: direct landfilling of sludge, chromium recovery prior to landfilling, and anaerobic digestion followed by oxidative chromium recovery and landfilling to investigate whether recovering chromium from tannery sludge reduce environmental impact of tanning. Bacardit et al. (2015) used LCA methodology to evaluate a patented alternative bovine leather processing system and compared to the existing traditional processes.

1.3. Leather processes and carbon footprint

Although LCA has proven its usefulness as a good environmental tool in quantifying the environmental burdens associated within life cycle stages of production processes, due to its wide scope and multiple impact categories, a higher worldwide trend of simplification (Baitz et al., 2013; Bala et al., 2010) focusing on a single indicator, carbon footprint, relevant to global warming (one of the impact categories evaluated through a LCA study) is gaining increasing interest. Carbon footprint (CF) of a product or service can be assessed at product level, following the LCA methodology for only this one impact category and following standards such as: PAS 2050 (2011), ISO 14067 (ISO 14067, 2013) or GHG Protocol for products (WBCSD, 2011b). It can also be assessed at corporate level, following standards such as: ISO 14064 (2006) or GHG corporate protocol (2004). Only a few studies have adopted a carbon footprint approach for the analysis of environmental burdens associated with leather production system. Chen et al. (2014) quantified the carbon footprints of the finished bovine leather in different thicknesses tanned in Taiwan through use of PAS 2050 (BSI PAS 2050, 2011). Some other studies focused on comparison of carbon footprint of alternative processes considering only the process under study. Kılıç et al. (2014) made some attempts and calculated greenhouse gas emissions and energy consumption associated with biodiesel production from tannery fleshings and further comparative assessment with rapeseed vegetable oil was also performed by the same authors (Kılıç et al., 2013). In another study carbon footprint of using a plant-derived biosurfactants in stead of conventional degreasing chemicals was reported by a preliminary work conducted by Kılıç et al. (2015b)

Xu et al. (2015) analyzed the environmental performance of a newly developed chromium-free tanning process compared to the conventional one in China. More recently GHG emissions derived from vegetable and chromium tanned leather processing technologies was

[1] Organisation for Economic Co-operation and Development.

calculated using data regarding water and energy resource usage from 12 tanneries in seven different countries such as Brasil, Mexico, China, Taiwan, Australia, Argentina and Spain (Laurenti et al., 2016).

1.4. Aim of the study

The literature review of the aforementioned LCA and carbon footprint studies on leather industry reveals that, in most of the studies, no verifiable individual inventory data is available and none of the published carbonfootprint and leather papers has a corporate carbon footprint approach. Therefore, further studies to elaborate detailed calculations of carbon footprints for leather industry are required. This fact is also highlighted by a UNIDO reports (Brugnoli, 2012; UNIDO, 2017). Additionally, LCA has never been applied to Turkish leather industry.

Nowadays, LCA and CF are topics of primary interest to tanners in industrialized countries (Redwood, 2013). However, considering the shifting of tannery production from industrialized countries to developing ones, Turkish tanning companies, especially those that are eager to present green credentials of their supply chains, should give particular attention to resource consumption and CO_2 emissions and be ready to apply the environmental impact assessment and protection trends prompted by environmental regulations when needed. Moreover, the projected emissions values of Turkey for 2025 is another important factor to increase the importance of monitoring and mitigating CO_2 emissions to improve leather companies sustainability (Lise, 2006; UNDP and WB, 2003).

Summarizing, there is a gap in the literature in adopting corporate carbon footprint approach for leather industry and, apparently, no publication can be found in the literature presenting inventory data for carbon footprint assessment of the Turkish leather industry. It is therefore important to analyze leather companies, in order to identify the hotspots and environmental improvements, which could transform the constraints into opportunities for improving the environmental performances of Turkish tanneries. The aim of our research is to provide basic information on a corporate carbon footprint of a sample Turkish tannery and raising awareness of carbon emissions and energy efficiency in Turkish leather production. This study adds up to the low number of corporate CF applications found in the literature and implements LCA methodology for the first time in Turkish tanneries (Kılıç et al., 2015a, 2015b). Results presented within this paper add scientific value by providing inventory data and information for identification of environmental “hotspots” of Turkish tanning processes in order to promote the implementation of effective carbon mitigation measures. This is in line with a recent United Nations Industrial Development Organization (UNIDO) report on life cycle assessment and carbon footprint of leather which suggests performing more studies on LCA regarding leather industry, and be aware of environmental impact assessment and protection trends in order to be ready at appropriate time when their implemention is needed (Brugnoli, 2012). Presenting inventory data is significant in terms of sectoral benchmarking and use of these benchmarks to reach sustainable leather production goals.

Additionally and most importantly this study has revealed that country specific emission factors for Turkey are not yet available. Turkish statistical reports and emission factors from other Mediterranean countries were used instead, together with default values obtained from IPCC (2006). The importance of publishing emission factors from local emission measurements to promote CF calculations in the country was also highlighted.

2. Methodology

In the present study corporate carbon footprint methodology, following the World Business Council for Sustainable Development Standards (WBCSD, 2011a) has been chosen to evaluate the greenhouse gases (GHG) emissions of a sample Turkish tanning company. Data was gathered for the year 2013. Corporate carbon footprint was calculated at three scopes (GHG corporate protocols, 2004 and 2011): Scope 1) direct emissions, Scope 2) indirect emissions from electricity production and Scope 3) indirect emissions upstream and downstream of the production chain. Direct GHG emissions occur from sources that are owned or controlled by the tanning company, for example, emissions from combustion in owned or controlled boilers, vehicles, etc. Scope 2 accounts for indirect GHG emissions from the generation of purchased electricity consumed by the tanning company. Other indirect GHG emissions that occur as a consequence of the activities of the tanning company, which derive from sources not owned or controlled by the company, (such as extraction and production of purchased materials; transportation of purchased fuels) are reported in Scope 3. Emissions from Scopes 1, 2 and 3 were quantified for 2013. Scope 3 categories included in the study were the following: category 1, emissions from purchased goods and services; category 3, fuel- and energy-related emissions not included in Scopes 1 and 2 and category 5, waste generated in operations.

However, to quantify Scope 3 emissions (of a certain raw material, fuel or the management of a certain waste) the use of LCA methodology (GHG corporate protocol, 2011) is required. LCA is a systematic way to evaluate the environmental impact of products by following a cradle-to-grave approach according to ISO 14040 standard (ISO 14040, 2006). Therefore, life cycle assessment methodology, has been used to quantitatively evaluate the environmental burdens due to indirect emissions (Scope 2 and Scope 3 emissions).

The carbon footprint analysis was performed by aid of the GaBi 6 software (Thinkstep), which included Life Cycle Inventories of energy and chemicals. The global warming potential was measured in kg of CO_2 equivalent emissions using the impact factors developed by Leiden University Centre of Environmental Science (CML), which were updated in 2009. Calculation was related to the annual processing of rawhide for shoe leather, manufactured by the studied Turkish tanning company, and the reference flow is 29,280 m^2 of finished hide. System includes the following phases: production and supply of electric energy, production of the main representative chemicals, beamhouse, tanning, dyeing, finishing, management of the wastewater, and transport of solid waste. The system boundaries are shown in Fig. 1.

2.1. Information about the tannery and data collection

The tannery under the study was established in a free zone that is considered as one of the important regions where Turkish leather manufacturers are located, with a gross built-up area of 12,500 m^2. Tannery has an annual total production capacity of 600,000 m^2 of finished leather for shoes and bags using chrome-tanning process. The corporate carbon footprint presented here corresponds only to the production of 29,280 m^2 of finished leather sold to a specific customer. The company collected and reported the inventory data being asked by its customer. Free Zone, where the tannery is located, has a water treatment plant facility with daily capacity of 8000 m^3 of wastewater, and a solid waste landfilling area.

Inventory data for 2013 was collected through a questionnaire with the following structure of information asked: i) general data about company and production process description, ii) inventory data on water and energy consumption, wastewater production, generation of both hazardous and non-hazardous solid waste, and direct fugitive emissions, and iii) purchased input material data including the quantity of purchased raw hide, chemicals, paper, and packaging materials. During 2013, the tanning company used 35 t of chemicals and consumed 38,594 m^3 of water to produce 29,280 m^2 finished calf hide (1 m^2 = 0.45 kg aprox), generating 410 metric tonnes of non-hazardous and 4.87 metric tonnes of hazardous solid waste. Only 15 t of non-hazardous waste is recyclable and was sent to reuse-recycling facility located at 260 km distance from tannery and the rest of the solid waste was sent to landfill area located in the industrial zone.

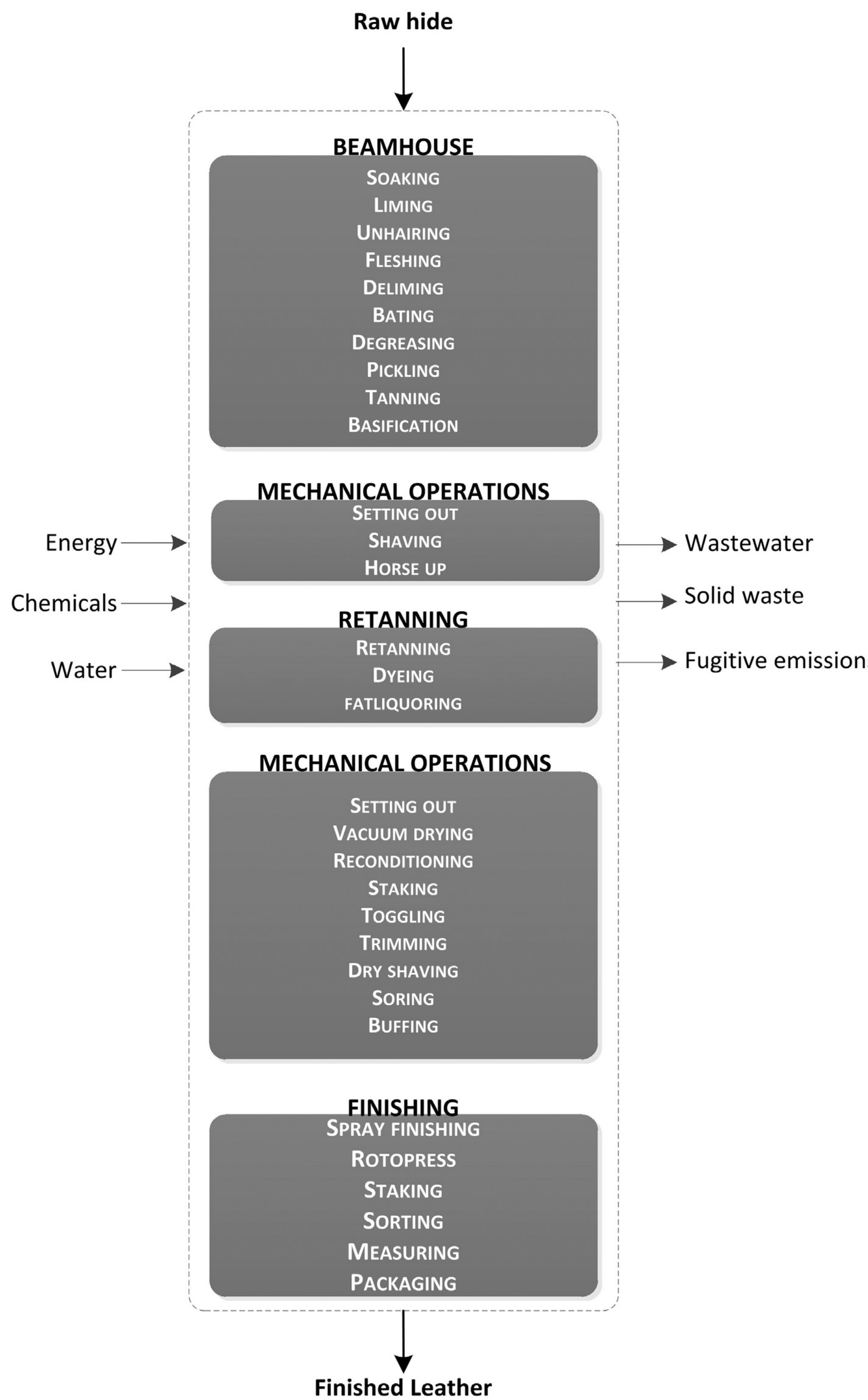

Fig. 1. Production processes of leather included in the study.

2.2. Assumptions for calculations

Emission factors used for the calculation of carbon footprint are mainly taken from Gabi Database, Intergovernmental Panel on Climate Change (IPCC, 2006) and from related U.S. Environmental Protection Agency's (EPA) documents. Total amount of chemicals used in leather production are distributed among the representative chemicals (sodium sulphur, lime, salt, sodium bicarbonate, chromium sulphate, surfactant, sulphuric acid, acetic acid, ammonium sulphate, kaolin, and resin), which correspond more than 70% of total chemical consumption.

Emission factor of chromium sulphate was calculated from emission factor of ferrous chrome (FeCr), (considering its molar ratio in its chemical formula) and for resin, melamine production process was assumed as a proxy. For the estimation of CH_4 emissions associated with treatment of organics in terms of COD and nitrogen in the effluent, default emission factor provided by IPCC (2006) was used. In order to calculate the impact assessment of the landfilling phase, the process structure and data were taken from the GaBi database (Thinkstep, 2015). Textile waste landfilling process described in the GaBi database was selected as proxy due to composition of organic and industrial waste that had

to be landfilled. Energy recovery was not considered in the landfilling process, because no energy recovery facility exists where the company transfers its wastes. Landfilling of solid wastes should be modelled more accurately in the next project. Another significant point is that currently no specific national data on electricity production technologies is available, therefore, although Turkish electricity mix was considered in the study, Mediterranean electricity production processes from different energy sources, (coal, natural gas, wind, solar, etc.) were used.

2.3. Electricity production in Turkey

Generation of electricity in Turkey is mainly based on imported fossil fuels. Turkey imports nearly 99% of the natural gas it consumes and over the last decade, it has been the second country following China, in terms of increase in natural gas demand (EMRA, 2016). Considering the projected growing demand for energy in Turkey and its dependency on expensive energy imports of fuels, implemention of energy policies that supports renewable energy gain significant importance. Despite the positive effects of such policies that went into effect in the last decade especially on hydropower potential which is raised by nearly 40% (Kucukali and Baris, 2011), hard coal and natural gas still hold the highest share comprising nearly 67% of total electricity supplies, while the use of renewable energies except hydropower for electricity production represents only 6.5%.

3. Results and interpretation

3.1. Inventory data from Turkish tannery

In this study a Turkish tannery has been environmentally evaluated and corporate carbon footprint results for the production of shoe leather from calf rawhide are presented. Table 1 shows the compiled inventory data of the tannery for the year 2013.

Turkish electricity mix shown in Fig. 2 (TEIAS, 2015) and Spanish electricity production technologies were considered, except for geothermal electricity production which is taken from Italy. This was used to obtain the CO_2 equivalent emissions derived from electricity production processes.

In order to calculate GHG emissions derived from industrial and domestic tap water consumption in the tannery, inventory data for water production processes is obtained from GaBi database. Transportation of solid wastes from tannery to landfilling and recovery facility is also considered in the study. Transportation of chemicals from the provider to the company was not included in the study due to lack of data.

Table 1
Inventory data from Turkish tannery in 2013.

		Source of emission	Quantity
Scope 1		Consumption of diesel in tannery [m^3]	37
		Consumption of natural gas in tannery [kW h]	2,285,300
		Refrigerant gas (R-134a) [kg]	2
Scope 2		Production of electricity [kW h]	797,310
Scope 3	Category 1	Production of sodium sulphur [kg]	3768.8
		Production of lime [kg]	3043.8
		Production of salt [kg]	16,250
		Production of sodium bicarbonate [kg]	3875
		Production of chromium sulphate [kg]	8062.5
		Production of surfactant [kg]	604
		Production of sulphuric acid [kg]	652
		Production of ammonium sulphate [kg]	242
		Production of kaolin [kg]	1367
		Production of resin [kg]	1198
		Production of paper [kg]	853.17
		Production of water for industrial purpose [m^3]	37,594
		Production of domestic water [m^3]	1000
	Category 3	Production of diesel [L]	37,000
		Production of natural gas [kW h]	2,285,300
	Category 5	Management of solid waste [kg]	414.870
		Treatment of wastewater [L] (3018 mg COD/L; 85 mg N/L)	27,000,000

3.2. Corporate CF results from Turkish tannery

Table 2 shows the carbon footprint results, together with the source of each emission considered in the calculation. Greenhouse gas emission values calculated for each scope and contribution of each scope to the total result was presented in Fig. 3. Scope 1 includes the emissions that arise directly from sources that are owned or controlled by the tannery, for example from fuels used for the vehicles that tannery owns. Scope 2 comprises the emissions generated by purchased electricity consumed by the tannery. And other indirect emissions, such as the production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the tannery, not covered in Scope 2, outsourced activities, waste disposal, etc., are considered in Scope 3. Scope 3 emissions were calculated in terms of purchased goods and services (category 1), fuel- and energy-related activities (category 3) and waste generated in operations (category 5).

Indirect emissions derived from upstream activities considered in Scope 3, have the highest contribution (45.2%) to total carbon footprint of 1849.3 t CO_2-eq. Landfilling of solid waste has a significant share in category 5 by 69% and emissions due to treatment of COD in effluents are the second highest contributer to this category by 30%. Landfilling is responsible for the 99% of the emissions derived from management of solid waste and only 1% of these emissions is related to transportation of solid waste into landfilling and recovery facility (see Fig. 4). Refrigerant gas used for general air conditioning of company has a significant contribution to carbon footprint of tannery, even though consumed in a considerably low amount.

Among the chemicals used in tanning processes, resin and chromium sulphate have the highest contribution to carbon footprint of tanning operations. It should be kept in mind that representative chemicals corresponding to majority of total chemicals were considered in the calculations and furthermore melamine and ferro chrome process data were used as proxy for the aforementioned chemicals respectively. Therefore more accurate data on production processes of chemicals and individual inventory data on the specific content of each chemical is needed for further studies. Chemical companies are beginning to deliver environmental life cycle information of their products, which will be very useful for industries using such chemicals, like tanneries. This study adopted a first approach to calculate carbon footprint using inventory data from proxy chemicals, but in further studies this approach can be improved when chemical production companies would provide more information about the CO_2 emissions due to production process of their chemicals.

Comparative carbon footprint results for each category considered in Scope 3 are shown in Fig. 5.

As seen from results in Fig. 4 production of chemicals play a minor role to the generation of GHG during the leather life cycle. This may be due to the use of simpler proxies to chemical substances, which can be found in Gabi database, instead of performing a life cycle assessment of the more sophisticated ones. This environmental profile can be improved with CO_2 emission data from the specific chemicals, provided by chemical producers.

Category 1 includes emissions from production of goods, category 3 evaluates fuel and energy related activities not included in Scope 1 or Scope 2, and finally emissions from residues generated in processes are included in category 5. Emissions related to waste management within category 5 have a significant relative contribution in Scope 3 (83%).

Finally, the relative contribution of different activities to total global warming potential, in terms of kg CO_2 equivalent, is presented in Fig. 6. Here, the different aspects are not classified in scopes, so the results presented in Fig. 6 don't follow the corporate carbon footprint standard (ISO 14064).

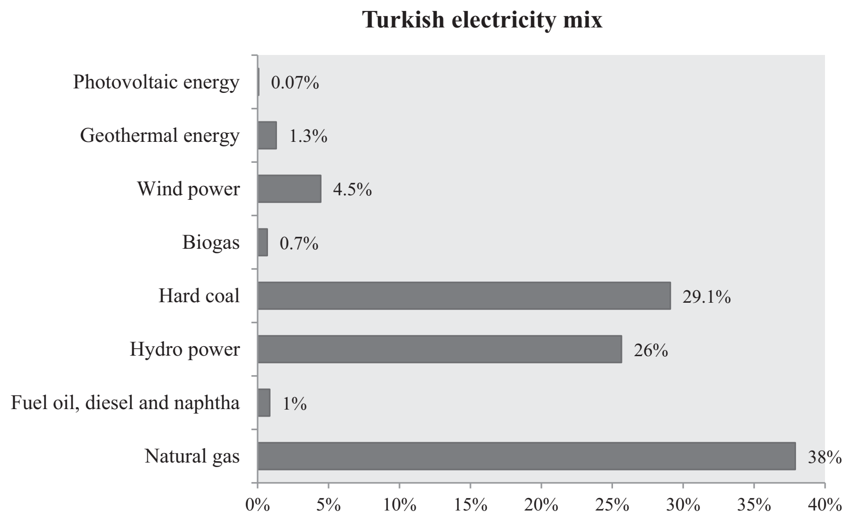

Fig. 2. Distribution of Turkey's electricity generation by energy sources (TEIAS, 2015).

Emissions from energy consumption, both in the form of fossil fuels and electricity, are notable. Natural gas has the highest contribution to green house gas emissions derived from energy use and the electricity use is among the most contributing phases. The significant contribution of waste management activities to global warming potential is mainly caused by the gaseous emissions (CH_4, NH_3) in the landfilling of organic wastes produced in the tannery. This high contribution of the waste management is in line with the previously reported studies and supports the remarkable impact of solid waste management phase of leather production when most of the waste is not recycled (Milà et al., 2002, 1998; Puig et al., 2001). Reduction of wastes together with a higher share of recycling and collection of biogas in landfill is suggested as an improvement possibility to mitigate the greenhouse gas emission generated during the landfilling phase.

3.3. Improvement recommendations for the tannery under study

Taking into account the findings of this study and other leather related LCA studies in the literature, some improvement actions that can be implemented to reduce the carbon footprint and enhance the environmental profile of the tannery are listed in Table 3.

Considering the results obtained from the current study, the two most important improvement opportunites to reduce the environmental impact of leather production are: minimizing the amount of waste generated, by increasing material recycling and reducing the use of combustibles and electricity, which are identified as significant hotspots of the system studied. Material recovery from solid waste implies both environmental and economic advantages, which results in lower quantity of waste disposal in landfill associated with lower emissions of NH_3

Table 2
Carbon footprint results from Turkish tannery.

Scopes		Source of emissions	CO_2 emission results [kg CO_2-eq]
Scope 1	Diesel	Emissions due to combustion (IPCC, 2006)	113,455.3
	Natural gas	Emissions due to combustion (IPCC, 2006)	459,345.3
	Refrigerant gas (R-134a)	Direct fugitive emissions (EPA, 2015)	2860
Scope 2	Electricity	Emissions due to production (Thinkstep, 2015)	437,225
Scope 3 (category 1)	Sodium sulphur	Emissions due to production (Winnipeg, 2011)	2409.5
	Lime (CaOH)	Emissions due to production (Thinkstep, 2015)	2431.3
	Salt	Emissions due to production (Thinkstep, 2015)	828.4
	Sodium bicarbonate	Emissions due to production (Thinkstep, 2015)	4746.4
	Chromium sulphate	Emissions due to production of ferrochrome (FeCr) (Thinkstep, 2015)	34,868.3
	Surfactant	Emissions due to production (Thinkstep, 2015)	519.4
	Sulphuric acid	Emissions due to production (Thinkstep, 2015)	168.2
	Acetic acid	Emissions due to production (Thinkstep, 2015)	278.3
	Ammonium sulphate	Emissions due to production (Thinkstep, 2015)	825.7
	Kaolin	Emissions due to production (Thinkstep, 2015)	391.7
	Resin	Emissions due to production (Thinkstep, 2015)	38,507.5
	Paper	Emissions due to production (Thinkstep, 2015)	981.1
	Water	Emissions due to production (Thinkstep, 2015)	142,076.4
Scope 3 (category 3)	Diesel	Emissions due to production (Thinkstep, 2015)	16,616.7
	Natural gas	Emissions due to production (Thinkstep, 2015)	81,609.2
Scope 3 (category 5)	Solid waste management	Emissions due to landfilling without gas recovery (Thinkstep, 2015)	350,685.9
	Transport	Emissions due to transportation of solid waste to landfill site [kg] (Thinkstep, 2015)	48.064
		Emissions due to transportation of solid waste to recovery site [kg] (Thinkstep, 2015)	234.39
	Wastewater treatment	Emissions due to treatment of COD load in effluent[kg] (IPCC, 2006)	152,786.25
		Emissions due to treatment of Nitrogen in effluent [kg] (IPCC, 2006)	5373.6
	Total carbon footprint		1849.27

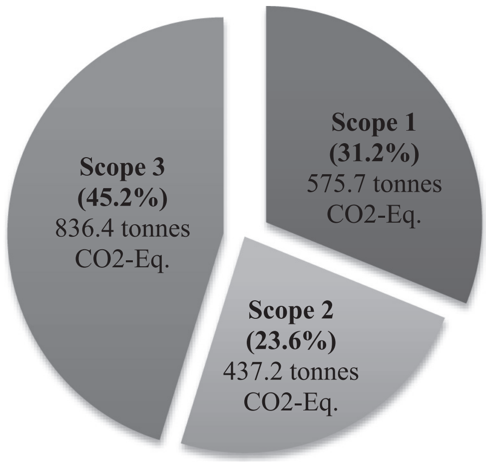

Fig. 3. Greenhouse gas emission values for each scope.

and CH_4 due to anaerobic degradation of the organic waste, and on the other hand reduced need for virgin raw materials such as fertilisers.

Energy use is closely linked to GHG emission, therefore energy conservation will result in a significant reduction in the carbon footprint of the studied company, due to its high electricity demand and the origin of this electricity. A country specific improvement suggestion for electricity would be: to encourage a change of the Turkish electricity mix (mainly based on hard coal and natural gas) to less carbon intensive fuels like natural gas and renewable energies.

Acquiring more accurate individual inventory data on inputs and outputs for chemicals is another suggestion that would enable obtaining results closer to reality.

Carbon footprint of leather is expressed in kg of CO_2-eq/m^2 of finished leather in order to supply product information to intermediate and final consumers and environmental key performance indicator of the tannery for the year of 2013 was calculated as 63.16 kg CO_2-eq emission/m^2 (28.4 kg CO_2-eq emission/kg) of finished calf leather. In following years if company would implement any of the aforementioned improvement suggestions in its production processes, this would enable company management to effectively quantify and evaluate the benefits of the adopted carbon reduction measures. Implementation of suitable environmental key performance indicator would also permit tracking the evolution of footprint of the company in progress of time.

3.4. Hypothetic results coming from the implementation of some improvement measures

Turkish electricity system is currently dominated by hydraulic, hard coal and natural gas power plants while renewable sustainable energy resources such as geothermal, waste, solar and wind have limited capacity. The characteristics of electricity production are of great importance, because they significantly affect the global warming potential due to energy consumption. If this production is based on renewable resources such as wind power, solar, and etc., its contribution will be minor. If the share of hard coal (29%) in electricity production of Turkey is substituted by solar, total carbon footprint of the tannery could be reduced by 15%. Taking into account the increasing dependency of Turkey on natural gas imports, improving the capacity of hydraulic and renewable energy resources would break the dependency on imported non-renewable energy resources and decrease the GHG emission as an additional advantage.

Other improvement options that could provide important benefits are increasing recovery, recycling ratio of solid waste sent to landfill and biogas recovery from landfilling area. Assuming that biogas recovery in the landfilling area of zone was performed in the current scenario, GHG emissions of tannery will be cut down by 1%. However on the other hand a significant mitigation rate of 23% can be achieved and reduce carbon footprint of tannery to 51.5 kg CO_2-eq/m^2 (23.18 kg CO_2-eq/kg) by landfilling of hazardous waste with biogas recovery and sent rest of the solid waste to recovery facility.

3.5. Contribution to Turkish Climate Change strategy

According to OECD (2016), Turkish is recently facing a rapid economic growth, which has to be rebalanced by increasing productivity and allow the most promising firms to grow faster. One of the areas where gains from progress should be large is Climate Change strategy. Although Turkish GHG emissions per capita are still low, they are increasing rapidly. In COP 21, Turkey announced his compromise to reduce 21% its emissions by 2030. Turkey's GHG emissions have increased by 110% between 1990 and 2013 (137% increase in energy sector, 132% in industrial processes, 20% in agriculture and 87% in waste sector) (OECD, 2016). An increase of about 600% emissions is foreseen by 2025 in the absence of policies to control GHG emissions (UNDP and WB, 2003). In order to avoid such increase and to contribute to Climate Change reduction, effective regulations and economic measures have to be implemented (ie. providing financial support to energy efficiency projects, increase the use of waste as an alternative fuel at the

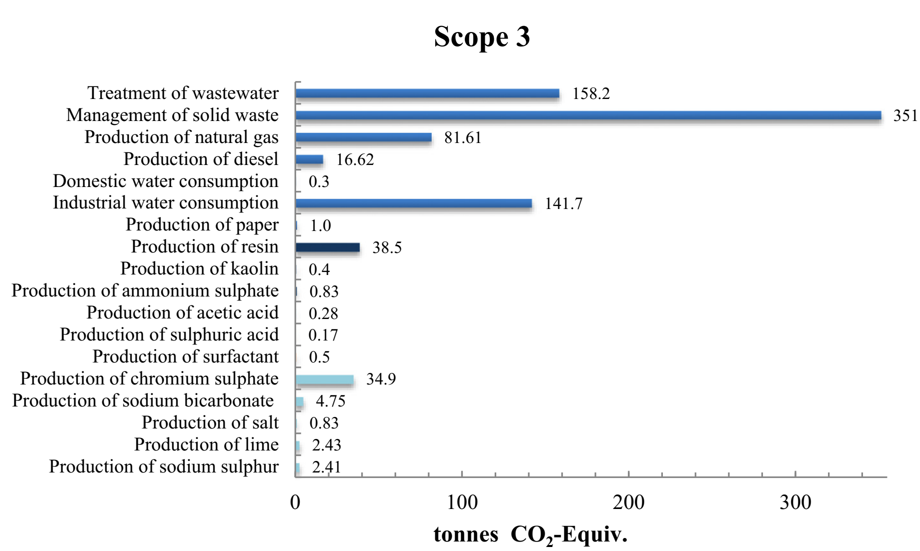

Fig. 4. Contribution of different processes considered in Scope 3 to total carbon footprint of tanning company.

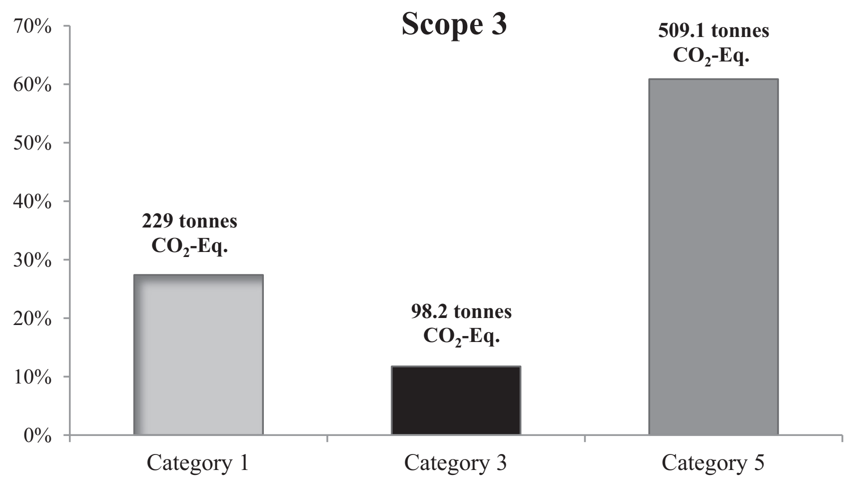

Fig. 5. Greenhouse gas emissions accounted for categories 1, 3 and 5 under Scope 3.

appropriate sectors, etc.) together with industrial emissions measuring and monitoring.

The present study is contributing to the latter strategy, industrial emissions measuring and monitoring, by providing a case study of a specific industry on how to measure and improve its carbon footprint.

One of the findings from the present study is the lack of country specific emission factors to calculate Scope 1 and Scope 2 emissions. It is necessary to provide official values for fuels, transport, and electricity production, to encourage Turkish companies to evaluate and reduce their corporate carbon footprint. This will enable companies to calculate their emissions and monitor the implementation of mitigation measures through use of key performance indicators. Moreover the emission reduction that would be achieved will help to reduce GHG emissions at country level.

As an example, if all tanning companies in Turkey had similar processes and emissions like the one studied here (63.16 kg CO_2/m^2 leather), as Turkey's leather production in Turkey in 2013 was 80 million pieces of bovine and 6.5 million pieces of ovine leather (TDSD, 2013) (and considering, according to the company, 1 piece ovine $\approx$ 0.6 m^2 and 1 piece bovine $\approx 3m^2$), the total GHG emissions of the country due to tanning industries would have been 4,263,300,000 kg CO_2. This represents a 0.93% of the total CO_2 emissions of Turkey as a country in that year (TUIK, 2013). If all tanning companies in Turkey used an electricity mix with higher renewable origin, such as hydro power 30%, wind power 25%, solar 30% and natural gas 15%, instead of the actual country grid mix that is based on fossil fuel, the GHG emissions of the Turkish tanning sector would be reduced by a 20%. These results reveal the necessity of restructuring energy supplies of Turkey and promote locally available sources especially wind and solar energy, which have a high potential in the country. This would also reduce Turkey's dependence on oil and gas imports, and provide safe energy procurement (Ilkiliç and Aydin, 2015).

In addition, if all tanning companies would be able to recycle their waste instead of taking it to the landfill, and/or landfills in Turkey had an energy recovery system, an additional reduction would be achieved.

It has to be said that both proposed alternatives (increasing the renewable sources on electricity production and promote energy recovery in landfills) are useful not only to decrease GHG emissions of tanning sector but also of other industries needing electricity for their processes and producing organic wastes. Considering the substantial contribution of industrial processes to the country carbon emissions and the importance of leather sector in Turkish economy, this reduction would provide a sound improvement in environmental profile of Turkey.

4. Conclusion

In this paper results from corporate carbon footprint assessment of a Turkish tanning company were presented. They show that emissions from disposal of both solid waste and wastewater (considered in Scope 3) and consumption of natural gas are hotspots of the tannery

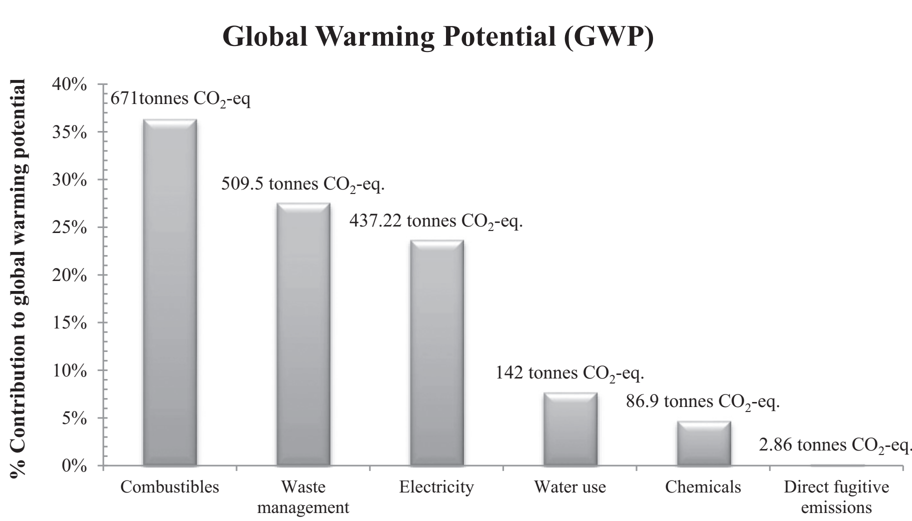

Fig. 6. Relative contribution of greenhouse gas emissions from different processes to total carbon footprint of Turkish tannery.

Table 3
Measures and recommendations for process improvement.

Issues	Improvement opportunities	References
Energy	Reduce electricity consumption Energy production based on renewable energy Improving machinery efficiency	Our study, (Milà et al., 2002, 1998)
Waste management	Biogas recovery from sludge Material recovery from solid waste Reduction of organic waste landfilled Waste volume reduction Reduce amount of packaging used	Our study, (Notarnicola et al., 2011), (Puig et al., 2007) (Milà et al., 2002)
Wastewater management	Reduce water consumption Seperate waste flows to enable chromium and salt recovery	Our study, (Milà et al., 2002)

and have the highest contribution to total carbon footprint. The carbon footprint of the tannery could be mitigated by waste reduction and recycling, increasing energy efficiency in tanning processes, collection of landfill biogas for energetic purposes and using an electricity grid mix with more contribution of renewable sources. The two last improvement options depend more on the country policy than on the companies themselves. The energy production profile of Turkey is mainly based on imported fossil fuels (OECD/IEA, 2016). Increasing the share of renewable energy in energy supply of Turkey could provide a remarkable reduction in emissions of greenhouse gases from the combustion of fossil fuels, while reducing Turkey's dependency on imported energy sources.

The work presented herein clearly depicts the fact that corporate carbon footprint can play a significant role by providing improvement options to industries, thus decreasing the total GHG emissions of a country. The awareness of diffuse emission sources contribution, like tanneries, to the country GHG emissions by policy makers is of great importance to implement measures for Climate Change mitigation at country level. To implement such measures and policies, national emission factors should be published to promote companies to measure and mitigate their GHG emissions.

Although the majority of Turkish tanners have limited awareness of their energy consumption and resultant carbon impacts, in order to keep up with foreseen demands from their clients and to compete in new markets they should audit their resource and energy consumptions as well as their carbon emissions. Furthermore, environmental assessments of individual tanneries will help set priorities for future improvements and will contribute to Turkish leather industry sustainability by providing data for benchmarking.

The results obtained from this study may provide a useful decision framework for incorporating sustainability concerns, follow-up of the most cost-effective carbon mitigation strategies and tackle with future carbon pollution regulations in Turkish leather industry. Additionally, potential reductions in greenhouse gases by promoting sustainable production and achieving the transition to a low carbon sustainable economy will provide new opportunities in the green market for Turkish industry.

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